DEVELOPMENT OF DIESEL ENGINES COOLING SYSTEM

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ABSTRACT

The current vehicle cooling system is using the water or water mixed with anti-freezing additive usually using ethylene glycol (EG) as the coolant in order to perform cooling process the circulating working fluids through the vehicle radiator. The project is carried out in demonstrating nearly similar condition for the actual condition. In this project, the heat transfer performance of distilled water and TiO_2 nanofluids with varied volume concentration is compared in the similar condition of the actual condition of temperature at radiator inlet, which from 90 °C to 60 °C. In addition, fluid flow rate also varied to compare the effect of different flow rate which 12 and 15 LPM to the heat transfer performance. The project gives the result that nanofluids clearly enhance heat transfer compared to their own base fluid. In the condition given, the best heat transfer enhancement of about 36.6 % compared to the base fluids has been recorded. The result gives the meaning that the typical coolant is could be replaced with nanofluids in order to have thermal transfer enhancement.

ABSTRAK

Sistem pendinginan enjin pada masa kini menggunakan air atau campuran air dengan bahan tambahan anti-pembeku yang biasanya menggunakan "*ethlyne glycol (EG)*" untuk untuk proses penyejukan cecair sistem pendinginan melalui radiator kenderaan. Projek ini dijalankan dalam keadaan yang mirip dengan keadaan sebenar ketika enjin beroperasi. Dalam projek ini, prestasi pemindahan haba air suling dan "*Titanium Dioxide nanofluids*" dibandingkan dimana kepekatan cecair ini diubah-ubah dan suhu perbandingan cecair ini adalah pada saluran kemasukan radiator, dimana pada 90 °C sehinnga 60 °C. Sebagai tambahan, kadar halaju aliran cecair juga diubah pada 12 LPM dan 15 LPM bagi membandingkan kesan perbezaan kadar aliran cecair ini terhadap prestasi pemindahan haba. Projek ini member hasil dimana "*nanofluids*" dengan jelas meningkatkan prestasi pemindahan haba berbanding dengan bendalir asas. Dalam kondisi yang terkawal, peningkatan haba tertinggi kira-kira 36.6 % berbanding dengan bendalir asas telah direkodkan. Hasil ujikaji ini menunjukkan bahawa kegunaan cecair penyejuk yang digunakan pada masa sekarang harus diganti dengan "*nanofluids*" dimana kadar pemindahan haba ditinggatkan berbanding bendalir asas.

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LIST OF SYMBOLS

D_i	Inner diameter of the tube, (*m*)
h	Convective heat transfer coefficient, ($W/m^2.K$)
k	Thermal conductivity, ($W/m.K$)
μ	Dynamic viscosity of the fluid, ($kg/m.s$)
ρ	Density of the fluid, (kg/m^3)
C_p	Specific heat, ($J/kg.K$)
l	Length of the tube, (*m*)
$\dot{m}$	Mass flow rate, (kg/s)
$\dot{Q}_{conv}$	Heat convection rate, (*Watt*)
$\dot{q}_s$	Heat Flux, (*W/m2*)
f	Friction factor
Nu	Nusselt number
Re	Reynolds number
Pr	Prandtl number
ΔP	Pressure difference
T_b	Bulk fluid temperature, (K)
T_s	Surface temperature, (K)
T_w	Wall temperature, (K)
ΔT	Temperature difference
ε	Roughness size, (*m*)
g	Gravitational acceleration, (m/s^2)
¨	Volume concentration of nanofluid
A_s	Surface area, (m^2)

V_{avg}	Average velocity, (m/s)
V	Voltage, (Volt)
I	Current, (Amphere)

LIST OF ABBREVIATIONS

HTC	Heat transfer coefficient
Al	Aluminum
Cu	Copper
Al_2O_3	Aluminum Oxide/Alumina
CuO	Copper Oxide
TiO	Titanium Oxide
SiC	Silicon Carbide
ZrO_2	Zirconia Oxide
LPM	Litre Per Minute
RPM	Revolution Per Minute
HP	Horse Power
HTR	Heat Transfer Rate
SDBS	Sodium Dodecyl Benzene Sulfonate
TDS	Total Dissolved Solids
CTAB	Cetyl trimethylammonium bromide

CHAPTER 1

INTRODUCTION

1.1 Introduction

Although vehicle technology by now was developed with sophisticated, but heat lost and efficiency lost during combustion in engine still become a challenging research theme for researchers all over the world.

Fuel consumption is tidily related to the efficiency of the engine combustion activity. As we know, the internal combustion engine only converts approximately one-third or 30 percent of the fuel energy to mechanical work in make vehicle moving. This is the fact at the present and it is extremely difficult to improve this internal combustion engine.

In this project, the most focusing is on the diesel engine cooling system, in which the diesel engine is operating at a high compression ratios as compared to gasoline engines. In order to ensure the life span of the engine, engine cooling system is necessitate to more efficiently. From the recent innovation and finding in nanotechnology which named nanofluids, improving the heat exchange system is possible with great potential in heat transfer enhancement from these nanofluids.

1.2 Problem Statement

The diesel engine is operating at high compression ratios as compared to gasoline engines. Due to its high compression ratio, the diesel engine produces higher heat when combustion reaction complete in each cycle. In order to afford this higher heat produced, the engine cylinder wall will be ticked that compared to the gasoline engine wall.

The cooling system is aimed to transfer the rejected heat produced from this combustion reaction. The rejected heat is a heat that engine unable to convert to a usefulness of mechanical energy. Thus, the diesel engine is needed to be more efficient to ensure the life span of the engine.

Current design of engine cooling system is normally used radiator, water pump and liquid water as cooling liquid. For this project, the cooling liquid will use water base nanofluids instead of liquid water.

1.3 Objectives

The purpose in the development of the diesel engine cooling system is based on several objectives. Those objectives are:

i. To develop an efficient diesel engine cooling system
ii. To design a new cooling system test rig
iii. To design a new coolant liquid for the cooling system

1.4 Scope

The project scope that categorized is design the diesel engine cooling system, the design and fabricates the test rig (water heater test rig), experimental test, and data analysis. The type of cooling system that will use in this project is vehicle diesel engine cooling system. This cooling system is target to use in Mitsubishi 4D56 diesel engine.

The cooling system will cover starting from the path of the system that circulates from the water pump, the radiator, the thermostat, and the passage inside the engine block and heads. The system will be developed by design the test rig for future real experiment application and TiO_2 nanofluids water based as a coolant instead of ethylene glycol. The parameter that involves is coolant temperature and flow rate which is the temperature at the radiator inlet temperature.

1.5 Thesis Organization

This thesis is divided into 6 chapters and each chapter is devoted to discuss the different issues in the project. Chapter 1 will discuss on introduction to the diesel engine cooling system and briefly in relation to nanofluids. The problem statement, objective and scope will be identified.

Chapter 2 will discuss about all the research and literature review that related to the project. Justification about aqueous alumina nanofluids that used to develop the system will also be discussed. Then, chapter 3 will discuss the approach and framework for the project. It explains about the method that is implemented while designing the system.

Chapter 4 will document all the processes that involve in the development of this project. Generally, this chapter explains about the designed project development. Finally, chapter 5 will discuss about the results and data analysis that had been acquired. The result included result analysis, project limitation and suggestions for project enhancement.

1.6 Project Flow Chart

The project will flow as in Figure 1.1 which the figure shows the process flow of the project with step by step start from the beginning of the project until the end.

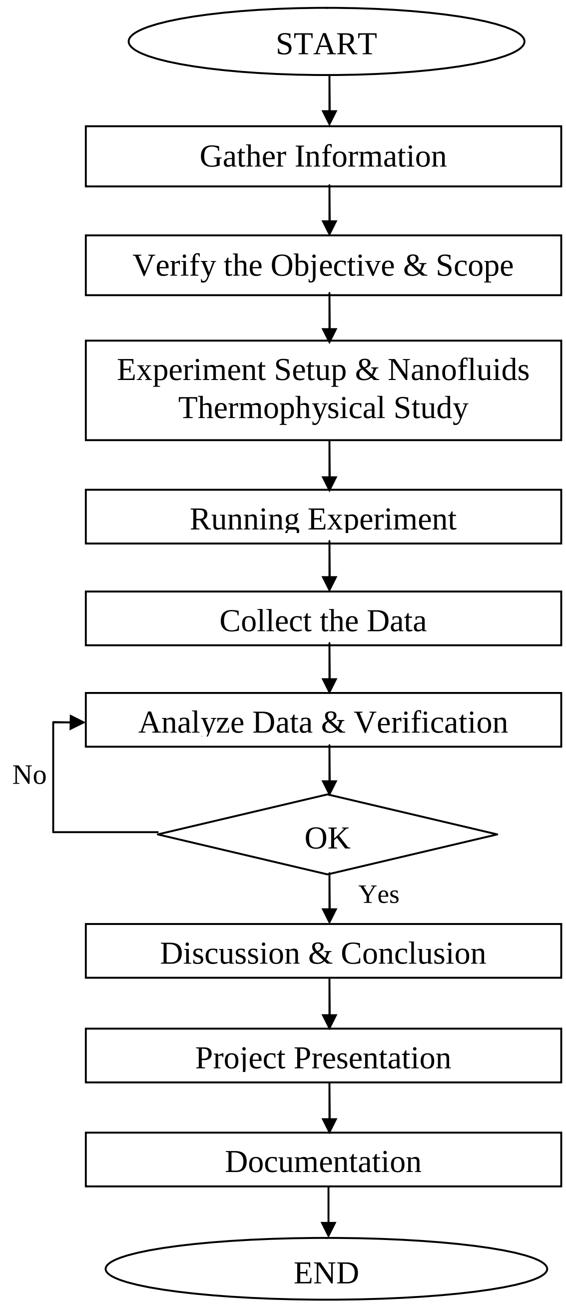

Figure 1.1: Project Flow Chart

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is very important for any research that will be done. The objective of this chapter two is aimed to present a selected literature review, which is very important for the research. This chapter also describes and explains on the literature review carried out on the system that will be used in developing this experiment research. Besides that, previous research also will be discussed in this section.

In this chapter, manufacturing process of nanofluids and applications nanofluids in industry will be explained. Then, several discussions in heat transfer theory together with dimensionless parameter related to this study organized by chronology to put in preparation for studies next, including effort research showed. Review detailed so that effort research showed could be properly booked to increase for board now literature and to makes sure the scope and direction of effort research are shown. Finally, in this end-of-chapter, the advantages and disadvantages of nanofluid will be enlightened.

2.2 Literature Review

Literature review targets to review the significant points of current research and knowledge on this field. Therefore, the purpose of the literature review is to find, read and analyze the literature or any works or studies related to this system. It is important to well understand about all information to be considered and related before start this experiment research.

For this project, some researchers have been done with knowing and understand about various nanofluids physical and thermal properties through many of experiment. In addition, a few researchers also carried out the experiment using nanofluids with applied to radiator or also called heat exchanger.

2.3 Background

The engines car has produce the high temperature of heat in reaction in the combustion chamber. In order to keep the temperature is in controlled temperature condition, coolant in cooling system is used to transfer the heat that produced from the engines to the ambient air.

In addition to this, the energy that produced in the engines is not all used but the only one-third will used as energy to move the vehicle and the other will used in overcome the friction force in the combustion chamber and others. And also one-third of the wasted energy is going to ambient environment by cooling system as heat dissipated. Increasing the efficiency of cooling system performance will reduce the energy wasted as the same time will increase the capacity of energy can produced with even the same capacity of cooling system that using more efficient cooling system.

The coolant that used in the vehicle is normally either water only or ethylene glycol mixed with water that usually used as typical coolant. This base fluids is known as conventional heat transfer fluids that have characteristic of poor heat transfer performance due to their low thermal conductivities. With compare to the solid metallic such copper, iron and non-metallic material such CuO, alumina, and carbon, nanotubes have much better thermal conductivities than this conventional fluids.

2.4 Nanofluids Innovation

The idea of using metallic particles to enhance the thermal conductivity of fluids is well known from Maxwell in 1881 (Maxwell, 1873), which come from the idea that how much better the coolant will work when mixed to this suspended particles of a conductor in the working fluids. It is well known that metallic material at solid state is having a much higher thermal conductivity than base fluids as look to the Table 2.1.

Table 2.1: Thermal Conductivity (W/m-K) of Various Materials at 300 K unless otherwise noted

Material	Thermal Conductivity
Metallic Solids	
Silver	429
Copper	401
Aluminum	237
Nonmetallic Solids	
Silicon	148
Metallic Liquids	
Sodium (at 644 K)	72.3
Nonmetallic Liquids	
Water	0.613
Engine oil	0.145

Source: Choi and Eastman, 1996

The beginning of the innovation is starting with millimeter and micrometer size solid particles blended into the base fluids. However, this thousand times greater size than nanoparticles that make constrain to the practical application of these nanoparticles which will settle out of the fluids and sink into the pipe or tank quickly.

Even the settling is preventing much with circulating the fluids rapidly, this bigger size of particles will caused the damage to the wall of the pipe, and increase the pressure drop and wearing the pipe thin (Zenghu Han, 2008). The effect also will affect the pump and bearing in the engine damage and wear when applied to the real application.

The changes of the scale from micro to nano sized particles are started by Choi and Eastman in Argonne National Laboratory revisited this field with their nanoscale metallic particle and carbon nanotube suspensions (Choi and Eastman, 1995 and Eastman et al., 1996). Choi and Eastman then have suspended various metal and oxide nanoparticles into several different fluids (Choi et al., 2001). This suspended fluid is then termed as "nanofluids" by Choi and Eastman.

2.5 Types of Nanofluids

Nanofluids are working fluids that dispersed with nanometer-sized particles with the range between 1 to 100 nm. Nanoparticles used in nanofluids have been made from various materials, such as oxide ceramics (Al_2O_3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO2, SiC), carbon nanotubes, and composite materials such as alloyed nanoparticles $Al_{70}Cu_{30}$ or nanoparticle core polymer shell composites.

In addition to nonmetallic, metallic, and other materials for nanoparticles, completely new materials and structures, such as materials "doped" with molecules in their solid liquid interface structure, may also have desirable characteristics. The common liquid normally used as a base fluid in nanofluid such as water, mineral oil and ethylene glycol. For this project, TiO_2 nanofluids that categorized is semiconductors material is used. There are six types of unit cells of nanofluids which are sphere, cube, hollow cube, slab-cross and column-cross nanoparticles, as we can see in Figure 2.1.

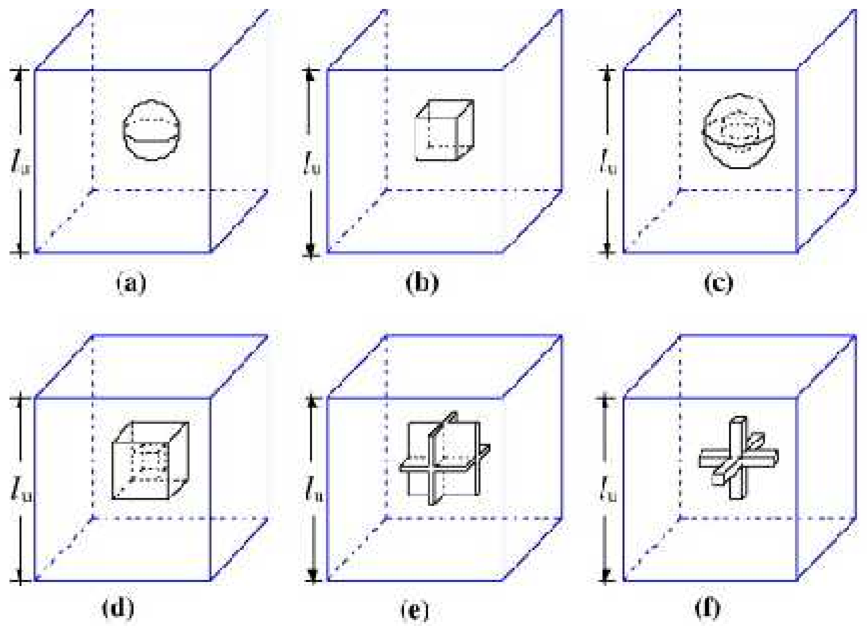

Figure 2.1: Unit Calls for Nanofluids Containing In-line Arrays of Spheres (a), Cubes (b), Hollow Spheres (c), Hollow Cubes (d), Slab-cross Particles (e), and Column-cross Particles (f)

Source: Jing Fan and Liqiu Wang, 2011

2.6 Technique of Nanoparticles Manufacturing

Nowadays, there are several processes in making of metal nanoparticles. The processes are Inert Gas Condensation (IGC), mechanical milling, chemical precipitation, thermal spray, and spray pyrolysis. Alloyed nanoparticles are the newest products that produced Al70Cu30 using ball milling, by Chopkar, et al., (2006).

In ball milling, balls impart a lot of energy to slurry of powder, and in most 9 cases some chemicals are used to cause physical and chemical changes. These nano sized materials are most commonly produced in the form of powders. In powder form, nanoparticles are dispersed in aqueous or organic host liquids for specific applications.

2.6.1 Dispersion of Nanoparticles in Liquids

There are two techniques to produce nanofluids which are single step and two step techniques. The single step techniques is simultaneously makes and disperses the nanoparticles directly into the base fluid and two step techniques starts with nanoparticles produced by one of the physical or chemical synthesis techniques and proceeds to disperse them into a base fluid.

Most of the nanofluids containing oxide nanoparticles and carbon nanotubes are produced by the two step process. In addition, an ultrasonic vibrator or magnetic stirrer was used to sonicate the solution continuously for approximately tenth hours in order to break down agglomeration of the nanoparticles.

2.7 Theory of Heat

Heat is defined as a form of energy that can be transferred from one system to another system as a result of temperature differences. Heat transfers is dealing with determination of the rates of such energy transfers and always occur from the higher temperature to lower temperature and is stop when the two mediums reach the thermal equilibrium condition.

Heat can be transferred in three different modes which are conduction, convection and radiation. All models require the existence of a temperature difference, and all modes from the high temperature medium to a lower one. For nanofluids flowing radiator through a plain tube, it is considered internal flow and heat is transferred by convection mode since it is involved fluid as a medium of heat transfer.

2.7.1 Thermal Conductivity

Thermal conductivity of a material is a measure of ability of material to conduct the heat. It defined as the rate of heat transfer through a unit thickness of the material per unit area per unit temperature difference. As shown in Figure 2.2, a high value for thermal conductivity indicates that the material is a good heat conductor and a low value indicates that the material is a poor heat conductor or insulator.

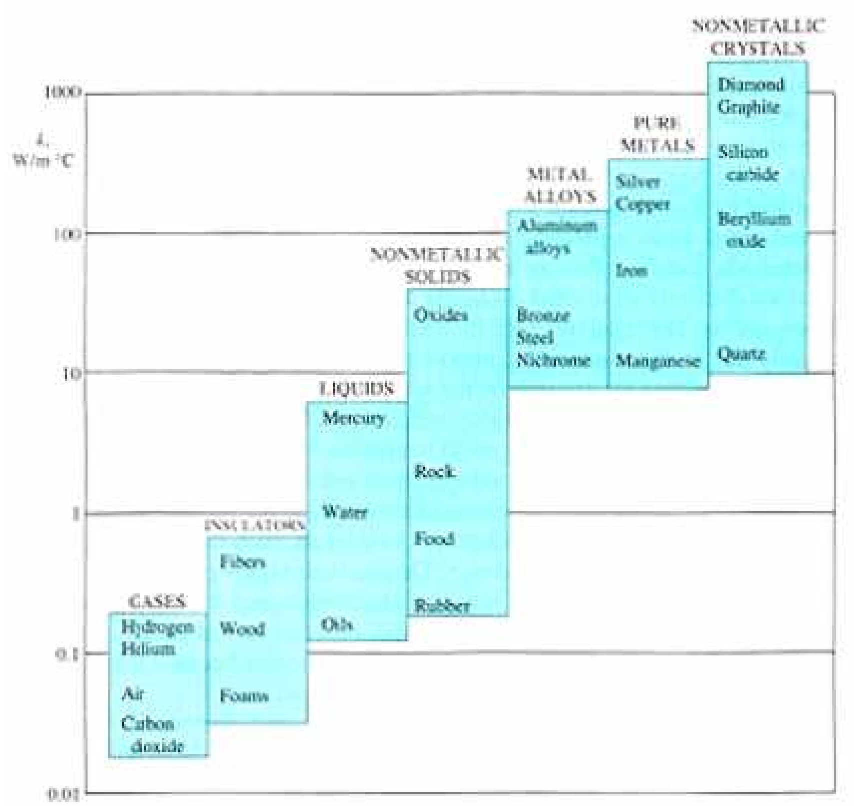

Figure 2.2: The Range of Thermal Conductivity of Various Materials at Room Temperature

Source: Cengel, 2006

Mostly researches on thermal conductivity of nanofluids are obtained at room temperature. The methods that use is hot-wire method and the conventional heat conduction cell method (Choi, 1996 and Lee et al., 1999). Other than this method, the recent published research has using the 3-ω method (Yang and Han, 2006). This 3-ω method is relatively accurate and uses a metal wire suspended in nanofluids.